[1] V.K. Konyukhov and A.M. Prokhorov, Author's Certificate (Patent) No. 223954, Priority 19 February 1966, Invention Bulletin No. 25, 1968.
[2] V.K. Konyukhov and A.M. Prokhorov, ZhETF Pis. Red. 3, 436 (1966) [JETP Lett. 3, 286 (1966)].
[3] N.G. Basov and A.N. Oraevskii, Zh. Eksp. Teor. Fiz. 44, 1742 (1963) [Sov. Phys.-JETP 17, 1171 (1963)].
[4] N.G. Basov, A.M. Oraevskii, and V.A. Shcheglov, Zh. Tekh. Fiz. 37, 339 (1967) and 38, 200 (1968) [Sov. Phys.-Tech. Phys. 12, 243 (1967) and 13, 143 (1968)].
[5] A.S. Biryukov, B.F. Gordiets, and A.A. Shelegin, Zh. Eksp. Teor. Fiz. 57, 585 (1969) [Sov. Phys.-JETP 30, 321 (1970)].
[6] V.N. Konyukhov, N.B. Matrosov, A.M. Prokhorov, D.T. Shalunov, and N.N. Shirokov, ZhETF Pis. Red. 10, 84 (1969) [JETP Lett. 10, 53 (1969)].
[7] A.P. Dronov, A.S. D'yakov, E.M. Kudryavtsev, and N.N. Sobolev, ibid. 11, 516 (1970) [11, 353 (1970)].
[8] D.M. Kuehn and D.T. Monson, Appl. Phys. Lett. 16, 48 (1970).
[9] B.R. Bronfin, L.R. Boedeker, and J.P. Cheyer, Appl. Phys. Lett. 16, 214 (1970).
[10] E.T. Gerry, IEEE, Spectrum 7, 51 (1970).

EXPERIMENTAL INVESTIGATION OF STOCHASTIC ACCELERATION OF IONS IN AN INTENSE PLASMA-BEAM DISCHARGE

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As shown in [1], in an intense pulsed plasma-beam discharge it is possible to distinguish between two regimes of excitation of low-frequency (LF) oscillations: the first regime (relatively low pressures) is characterized by excitation of ion-acoustic oscillations [2], which go over in time (after 30 - 40 μsec) into oscillations pertaining to the second regime. The second regime includes also oscillations generated during the entire duration of the current pulse at higher gas pressure of the system (above 6×10^{-4} Torr), since for these oscillations the first regime lasts only several microseconds.

We present in this paper results of an investigation of the stochastic acceleration of ions in the excitation of LF oscillations in the second regime.

The experiments were performed with a setup [2] having the following parameters: electron beam current 5 A, energy 10 - 12 keV, current pulse duration 110 μsec, electron density of the plasma produced by the beam 5×10^{12} - 2×10^{13} cm^{-3}, longitudinal magnetic field intensity up to 2 kOe, working gas - hydrogen.

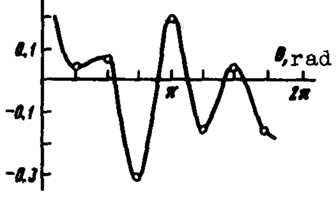

Fig. 1

Using the procedure of computer reduction of the experimentally obtained realizations [1], we determined the following characteristics: the function of mutual correlation of the oscillations in azimuth, the space-time correlation function, the frequency spectrum and the spectral energy density of the excited oscillations; we also investigated the time variation of the phases of the investigated oscillations.

The oscillations in the second regime, unlike in the first, are axially-asymmetrical. Figure 1 shows the function of the mutual correlation of the excited oscillations in azimuth, obtained with the aid of antennas located outside the plasma chamber in one plane and oriented along the H_ϕ component of the LF field (longitudinal magnetic field intensity 1700 Oe, pressure (2 - 3) × 10^{-4} Torr). We see that the periphery subtends over four maxima. For a pressure 6 × 10^{-4} Torr, this curve has a similar character with a shift of the maxima by approximately 45°.

Figure 2 shows the following: a) one of the realizations x(t) of the oscillations excited in the second regime, b) the frequency spectrum $S_{xx}(f)$, c) the spectral energy density of these oscillations $S_k(\omega)$ for $k = 0.1\ \text{cm}^{-1}$, d) the time variation of the phase $\phi(t)$ of the investigated oscillations, e) the energy spectrum of the ions generated upon excitation of LF oscillations under the conditions of the second regime.

It is seen from this figure that the oscillations in the second regime are characterized by a smearing of the frequency spectrum, by an increase of the relative half-width of the spectral density $S_k(\omega)$ ($\Delta\omega/\omega \sim 1.2 - 1.5$), and by the presence of jumps of the phases of the electric field (∿150°). The correlation time $\tau_k \sim 1/\Delta\omega$ amounts to (1.5 - 2) × 10^{-6}sec, and the average time between phase jumps is $\tau' \sim 1.5 \times 10^{-6}$ sec.

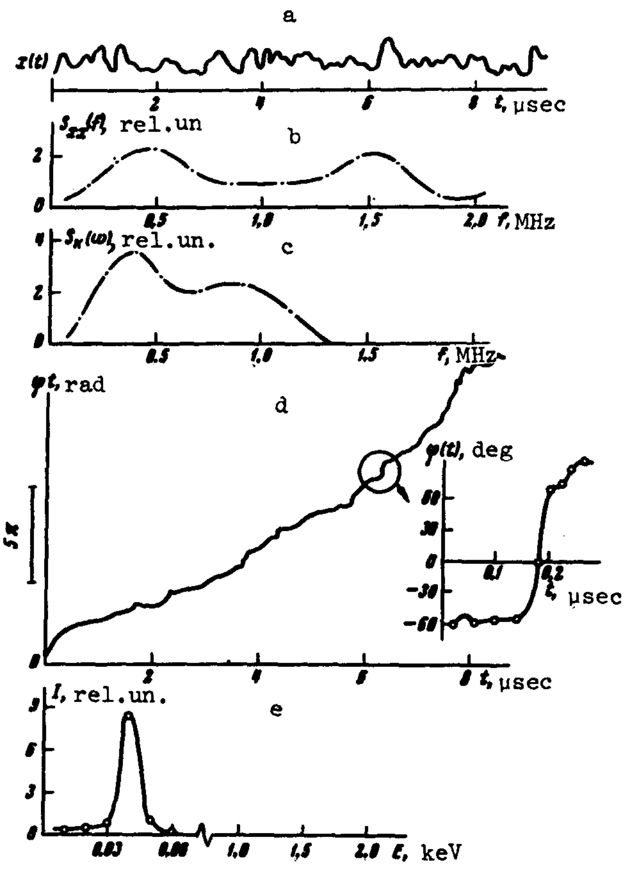

Fig. 2

As is well known, the frequency of the drift oscillations is given by

$$\omega_{dr} = \frac{k_\perp T_e c}{eH} \frac{\nabla n}{n}, \tag{1}$$

where $k_\perp$ is the transverse wave number, T_e the temperature of the plasma electrons, c the velocity of light in vacuum, e the electron change, H the longitudinal magnetic field intensity, n the plasma density, and ∇n the density gradient.

It follows from the foregoing experiments that the frequencies of the excited oscillations are $f \sim H^{-1}$ and are proportional to the electronic plasma temperature T_e. It should be noted that for our conditions, T_e changes from 80 - 100 to 20 - 30 eV when the pressure changes from 2 × 10^{-4} to 6 × 10^{-4} Torr [3].

The presented relations allow us to conclude that drift LF oscillations are excited in the second regime.

It was shown earlier [3] that under conditions of the second regime there was observed generation of low-energy ion currents (energy 40 eV, current ~ 2 A, ion density 2×10^{12} cm^{-3} at a plasma density 2×10^{13} cm^{-3}).

From a comparison of the time of flight of the particles with velocity v over the length of the system L ($\tau \sim L/v$, $L \sim 70$ cm) with the average time (τ') between neighboring jumps of the phases we can draw a conclusion concerning the model on which the proposed acceleration mechanism is based. If $\tau \sim \tau'$ (which is characteristic of oscillations of the first regime) it can be assumed that the acceleration of the ions is effected by the electric field of the ion-acoustic wave with fixed phase. If $\tau > \tau'$ (second oscillation regime of the LF oscillations), then the acceleration of the ions can be explained by using the stochastic-acceleration model (wave with random phase). The velocity of the accelerated particles is then given by [4]

$$v = \frac{4e^2}{M^2} \frac{kE^2\omega\tau^3\Delta t}{(1 + \omega^2\tau^2)^2}, \qquad (2)$$

where e and M are the charge and mass of the ion, k the wave number, ω the oscillation frequency, E the electric field intensity, and Δt and τ the flight and correlation times.

The corresponding calculation of the field intensity for our case ($\omega \sim 3 \times 10^6$ sec^{-1}, $\Delta t \sim 8 \times 10^{-6}$ sec, $\tau \sim 2 \times 10^{-6}$ sec, $v \sim 9 \times 10^6$ cm/sec) yield $E \sim 15$ V/cm. The experimentally determined value is $E \sim 20$ V/cm, which confirms the possibility of the assumptions made above.

Thus, we have investigated the LF oscillations and the mechanisms of energy transfer from the electron beam to the plasma ions in the second regime of an intense plasma-beam discharge.

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[1] G.P. Berezina, A.K. Berezin, and V.P. Zeidlits, ZhETF Pis. Red. 14, 13 (1971) [JETP Lett. 14, 8 (1971)].
[2] A.K. Berezin, Ya.B. Fainberg, L.I. Bolotin, G.P. Berezina, I.A. Bez'yazychnyi, Yu.M. Lyapkalo, and E.V. Lifshitz, Plasma Physics and Controlled Nuclear Fusion Research 1, 515 (1966).
[3] G.P. Berezina, Ya.B. Fainberg, and A.K. Berezin, Phenomena in Ionized Gases, Vienna, 370, 1967; Atomnaya energiya 24, 465 (1968).
[4] F.G. Bass, Ya.B. Fainberg, and V.D. Shapiro, Zh. Eksp. Teor. Fiz. 49, 329 (1965) [Sov. Phys.-JETP 22, 230 (1966)].

FRACTIONIZATION OF CARBON ISOTOPES IN THE SYNTHESIS OF DIAMONDS FROM GAS

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The synthesis of diamonds from gas occurs in the region of metastability of diamond and is based on the orienting action of the surface forces of the primer on the nucleation processes [1, 2]. The growth of the priming diamond powders (natural and synthetic diamond) revealed a previously unknown phenomenon, namely anomalously large fractionization of stable isotopes of carbon.